

PATENT  
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ASYNCHRONOUS CONFIGURATION

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CROSS-REFERENCE TO RELATED APPLICATIONS

5 [0001] This application is related to the following co-pending and commonly-assigned patent applications, which applications are incorporated by reference herein:  
[0002] United States Patent Application Serial No. xx/xxx,xxx, entitled "MULTIPLE NONVOLATILE MEMORIES", by Ronald Cocchi, et. al., Attorney Docket No. PD-200335, filed on the same date herewith;

10 [0003] United States Patent Application Serial No. xx/xxx,xxx, entitled "HIDDEN IDENTIFICATION", by Ronald Cocchi, et. al., Attorney Docket No. PD-200336, filed on the same date herewith; and  
[0004] United States Patent Application Serial No. xx/xxx,xxx, entitled "DEDICATED NONVOLATILE MEMORY", by Ronald Cocchi, et. al., Attorney Docket No. PD-200337, filed on the same date herewith.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0005] The present invention relates to systems and methods for limiting unauthorized access 20 to digital services and in particular to a method and system for incorporating a hardware based asynchronous configuration mechanism in a smart card capable of dynamically reconfiguring a hardware state machine using a secure delivery process.

2. Description of the Related Art

25 [0006] Digital services such as television programs and information regarding those programs (e.g., a program guide) are distributed to users by a variety of broadcasting methods. Such services may be proprietary and available on a subscription basis. To prevent unauthorized access to the services, a plethora of security mechanisms are utilized. Such mechanisms may

store information in memory, wherein the information is used to validate a user or provide access. However, persons often attempt to obtain illegal/unauthorized access to the services by altering the memory contents. What is needed is the capability to prevent or increase the difficulty of obtaining illegal access to the information and digital services. These problems may

5 be better understood by a description of current broadcasting methods, security mechanisms, and methods for obtaining unauthorized access to such services.

[0007] As described above, television programs and digital services are distributed to viewers by a variety of broadcasting methods. These methods include traditional analog broadcast television (National Television Standards Committee or "NTSC" standard), the soon to be 10 required digital broadcast television (Advanced Television Systems Committee or "ATSC" standard), cable television (both analog and digital), satellite broadcasting (both analog and digital), as well as other methods. These methods allow channels of television content to be multiplexed and transmitted over a common transmission medium.

[0008] To view the television programming and have access to the digital services, users 15 commonly have a set top box (also referred to as an integrated receiver/decoder [IRD]). Within the system or set top box, a security component/microcircuit known as a smart card may be utilized to prevent unauthorized access to the television programs and digital services. The smart card microcircuit may contain a microprocessor, volatile memory components, a nonvolatile memory component, and a system input/output module. The security system may be 20 compromised if components are attacked or used in unintended ways.

[0009] Nonvolatile memory has been used extensively throughout the electronics industry. For example, in the IRD, the microprocessor utilizes nonvolatile memory to contain state 25 information (e.g., status information) used to provide the desired functionality and enforce security policies intended by the designers. The microprocessor and/or a memory access control unit utilized by the microprocessor restricts access to the memory components.

[0010] In the prior art, virtually all successful security compromises to alter system software contained in nonvolatile memory have been through external, non-invasive attacks using the system input/output module. Such compromises may merely require a computer and an

inexpensive (e.g., \$10) card reader. Thus, most attacks occur by inappropriate manipulation of the microprocessor or memory access control unit.

[0011] For example, there have been numerous attempts by individuals or companies (i.e., hackers or attackers) to attack, misuse, or modify the nonvolatile memory through external

5 means of reprogramming or otherwise altering the contents of the memory when the memory component has been available to the central processor or otherwise on the system bus. For example, attacks using unforeseen methods or subverting poorly implemented defenses can be used to gain unauthorized access to the contents of the memory and/or lead to reprogramming the contents of the memory. Reprogramming or unauthorized access to the memory contents

10 can lead to complete compromise of the security features intended in the device.

[0012] The simplest and most prevalent form of attack against the memory components uses external noninvasive means using a system's input/output module due to the low cost of the equipment required to implement this form of attack. Most attacks occur by inappropriate manipulation of a microprocessor or memory access control unit. For example, memory

15 contents have been subverted when a memory access control unit (that controls access to a memory component) has been compromised. Once the single memory component has been breached, the attacker may then have the capability to access all memory address locations that reside other memory components.

[0013] To avoid security compromises through system software and the nonvolatile memory, 20 some prior art techniques also employ custom hardware within the smart card. The custom hardware provides a hardware state machine that implements a security policy. However, such a hardware state machine is fixed. Accordingly, if the hardware is compromised, the smart card must be physically replaced to accommodate a different hardware state machine. Such a replacement can be extremely expensive if the deployed customer base is large.

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#### SUMMARY OF THE INVENTION

[0014] Digital services systems often contain a security component known as a smart card to prevent unauthorized access to the services. The smart card microcircuit contains a

microprocessor, volatile memory components, nonvolatile memory components, a custom logic block, and a system input/output module. The security system may be compromised if memory components are used or attacked in unattended ways typically through the system input/output module.

5 [0015] One or more embodiments of the invention provide a method, apparatus, and article of manufacture for incorporating a hardware based, asynchronous configuration mechanism in a smart card capable of dynamically reconfiguring a hardware state machine using a secure delivery process from the head-end. A head-end encrypts a configuration key and delivers the key to the smart card through the broadcast stream, Internet, callback or other appropriate 10 distribution channel. The implementation is hidden from the microprocessor by placing the decryption engine and configuration mechanism in a hardware state machine. Since the implementation is hardware based, it is protected from being altered by the microprocessor or external means. The decryption engine and configuration mechanisms are secure because they are not directly accessible by the system input/output module or system bus.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

[0017] FIG. 1 is a diagram showing an overview of a video distribution system;

20 [0018] FIG. 2 is a block diagram showing a typical uplink configuration showing how video program material is uplinked to a satellite for transmission to subscribers using a single transponder;

[0019] FIG. 3 is a block diagram of one embodiment of the program guide subsystem;

[0020] FIG. 4A is a diagram of a representative data stream received from a satellite;

25 [0021] FIG. 4B is a diagram illustrating the structure of a data packet;

[0022] FIG. 5 is a block diagram of one embodiment of an integrated receiver/decoder;

[0023] FIG. 6 illustrates the architecture of a conditional access module in accordance with one or more embodiments of the invention;

[0024] FIG. 7 illustrates the architecture of a custom logic block in accordance with one or more embodiments of the invention; and

[0025] FIG. 8 is a flowchart illustrating the use of the custom logic block to provide access to digital services in accordance with one or more embodiments of the invention.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0026] In the following description reference is made to the accompanying drawings which form a part hereof and which show, by way of illustration, several embodiments of the present invention. It is understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

## Overview

[0027] One purpose of this invention is to protect the smart card from allowing unauthorized viewing. Accordingly, embodiments are specifically designed to prevent external, noninvasive attacks. Protection is achieved through implementation of the invention in custom dynamically reconfigurable hardware contained in the smart card.

## Video Distribution System

[0028] FIG. 1 is a diagram illustrating an overview of a single satellite video distribution system 100. The video distribution system 100 comprises a control center 102 in communication with an uplink center 104 via a ground or other link 114 and with a subscriber receiver station 110 via a public switched telephone network (PSTN) or other link 120. The control center 102 provides program material (e.g. digital services, video programs, audio programs and data) to the uplink center 104 and coordinates with the subscriber receiver stations 110 to offer, for example, pay-per-view (PPV) program services, including billing and associated decryption of video programs.

[0029] The uplink center 104 receives program material and program control information from the control center 102, and using an uplink antenna 106 and transmitter 105, transmits the

program material and program control information to the satellite 108 via uplink 116. The satellite receives and processes this information, and transmits the video programs and control information to the subscriber receiver station 110 via downlink 118 using transmitter 107. The subscriber receiving station 110 receives this information using the outdoor unit (ODU) 112,

5 which includes a subscriber antenna and a low noise block converter (LNB).

[0030] The subscriber receiving station 110 permits the use/viewing of the information by a subscriber 122. For example, the information may be used/viewed on a television 124 or other display device. To control access to the information, the subscriber receiving station 110 includes an integrated receiver/decoder (IRD) 126. In embodiments of the invention, the IRD

10 126 is communicatively coupled to a security component known as a conditional access module or smart card that controls access to the information/digital services.

[0031] In one embodiment, the subscriber receiving station antenna is an 18-inch slightly oval-shaped Ku-band antenna. The slight oval shape is due to the 22.5 degree offset feed of the LNB (low noise block converter) which is used to receive signals reflected from the subscriber 15 antenna. The offset feed positions the LNB out of the way so it does not block any surface area of the antenna minimizing attenuation of the incoming microwave signal.

[0032] The video distribution system 100 can comprise a plurality of satellites 108 in order to provide wider terrestrial coverage, to provide additional channels, or to provide additional bandwidth per channel. In one embodiment of the invention, each satellite comprises 16 20 transponders to receive and transmit program material and other control data from the uplink center 104 and provide it to the subscriber receiving stations 110. Using data compression and multiplexing techniques the channel capabilities, two satellites 108 working together can receive and broadcast over 150 conventional (non-HDTV) audio and video channels via 32 transponders.

25 [0033] While the invention disclosed herein will be described with reference to a satellite-based video distribution system 100, the present invention may also be practiced with terrestrial-based transmission of program information, whether by broadcasting means, cable, or other means. Further, the different functions collectively allocated among the control center 102

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and the uplink center 104 as described above can be reallocated as desired without departing from the intended scope of the present invention.

[0034] Although the foregoing has been described with respect to an embodiment in which the program material delivered to the subscriber 122 is video (and audio) program material such 5 as a movie, the foregoing method can be used to deliver program material comprising purely audio information or other data as well.

#### Uplink Configuration

[0035] FIG. 2 is a block diagram showing a typical uplink configuration for a single satellite 10 108 transponder, showing how video program material is uplinked to the satellite 108 by the control center 102 and the uplink center 104. FIG. 2 shows three video channels (which could be augmented respectively with one or more audio channels for high fidelity music, soundtrack information, or a secondary audio program for transmitting foreign languages), a data channel from a program guide subsystem 206 and computer data information from a computer data 15 source 208.

[0036] The video channels are provided by a program source of video material 200A-200C (collectively referred to hereinafter as video source(s) 200). The data from each video program source 200 is provided to an encoder 202A-202C (collectively referred to hereinafter as encoder(s) 202). Each of the encoders accepts a program time stamp (PTS) from the 20 controller 216. The PTS is a wrap-around binary time stamp that is used to assure that the video information is properly synchronized with the audio information after encoding and decoding. A PTS time stamp is sent with each I-frame of the MPEG encoded data.

[0037] In one embodiment of the present invention, each encoder 202 is a second generation Motion Picture Experts Group (MPEG-2) encoder, but other decoders implementing other 25 coding techniques can be used as well. The data channel can be subjected to a similar compression scheme by an encoder (not shown), but such compression is usually either unnecessary, or performed by computer programs in the computer data source (for example, photographic data is typically compressed into \*.TIF files or \*.JPG files before transmission).

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After encoding by the encoders 202, the signals are converted into data packets by a packetizer 204A-204F (collectively referred to hereinafter as packetizer(s) 204) associated with each source 200.

5 [0038] The data packets are assembled using a reference from the system clock 214 (SCR), and from the conditional access manager 210, which provides the SCID to the packetizers 204 for use in generating the data packets. These data packets are then multiplexed into serial data and transmitted.

Program Guide Subsystem

10 [0039] FIG. 3 is a block diagram of one embodiment of the program guide subsystem 206. The program guide data transmitting system 206 includes program guide database 302, compiler 304, sub-databases 306A-306C (collectively referred to as sub-databases 306) and cyclers 308A- 308C (collectively referred to as cyclers 308).

15 [0040] Schedule feeds 310 provide electronic schedule information about the timing and content of various television channels, such as that found in television schedules contained in newspapers and television guides. Schedule feeds 310 preferably include information from one or more companies that specialize in providing schedule information, such as TRIBUNE MEDIA SERVICES™, and T.V. DATA™. The data provided by companies such as TRIBUNE MEDIA SERVICES™ and T.V. DATA™ are typically transmitted over telephone lines to program guide database 302. These companies provide television schedule data for all of the television stations across the nation plus the nationwide channels, such as SHOWTIME™, HBO™, and the DISNEY CHANNEL™. The specific format of the data that are provided by these companies varies from company to company. Program guide database 302 preferably includes schedule data for television channels across the entire nation 20 including all nationwide channels and local channels, regardless of whether the channels are transmitted by the transmission station.

25 [0041] Program guide database 302 is a computer-based system that receives data from schedule feeds 310 and organizes the data into a standard format. Compiler 304 reads the

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standard form data out of program guide database 302, identifies common schedule portions, converts the program guide data into the proper format for transmission to users (specifically, the program guide data are converted into objects as discussed below) and outputs the program guide data to one or more of sub-databases 306.

- 5    [0042] Program guide data can also be manually entered into program guide database 302 through data entry station 312. Data entry station 312 allows an operator to enter additional scheduling information, as well as combining and organizing data supplied by the scheduling companies. As with the computer organized data, the manually entered data are converted by the compiler into separate objects and sent to one or more of sub-databases 306.
- 10   [0043] The program guide objects are temporarily stored in sub-databases 306 until cyclers 308 request the information. Each of cyclers 308 may transmit objects at a different rate than the other cyclers 308. For example, cycler 308A may transmit objects every second, while cyclers 308B and 308C may transmit objects every 5 seconds and every 10 seconds, respectively.
- 15   [0044] Since the subscriber's receivers may not always be on and receiving and saving objects, the program guide information is continuously re-transmitted. Program guide objects for programs that will be shown in the next couple of hours are sent more frequently than program guide objects for programs that will be shown later. Thus, the program guide objects for the most current programs are sent to a cycler 308 with a high rate of transmission, while 20 program guide objects for later programs are sent to cyclers 308 with a lower rate of transmission. One or more of the data outputs 314 of the cyclers 308 are forwarded to the packetizer of a particular transponder, as depicted in FIG. 2.
- 25   [0045] It is noted that the uplink configuration depicted in FIG. 2 and the program guide subsystem depicted in FIG. 3 can be implemented by one or more hardware modules, one or more software modules defining instructions performed by a processor, or a combination of both.

## Broadcast Data Stream Format and Protocol

[0046] FIG. 4A is a diagram of a representative data stream. The first packet segment 402 comprises information from video channel 1 (data coming from, for example, the first video program source 200A). The next packet segment 404 comprises computer data information that was obtained, for example from the computer data source 208. The next packet segment 406 comprises information from video channel 5 (from one of the video program sources 200). The next packet segment 408 comprises program guide information such as the information provided by the program guide subsystem 206. As shown in FIG. 4A, null packets 410 created by the null packet module 212 may be inserted into the data stream as desired.

[0047] The data stream therefore comprises a series of packets from any one of the data sources in an order determined by the controller 216. The data stream is encrypted by the encryption module 218, modulated by the modulator 220 (typically using a QPSK modulation scheme), and provided to the transmitter 222, which broadcasts the modulated data stream on a frequency bandwidth to the satellite via the antenna 106. The receiver 126 receives these signals, and using the SCID, reassembles the packets to regenerate the program material for each of the channels.

[0048] FIG. 4B is a diagram of a data packet. Each data packet (e.g. 402-416) is 147 bytes long, and comprises a number of packet segments. The first packet segment 420 comprises two bytes of information containing the SCID and flags. The SCID is a unique 12-bit number that uniquely identifies the data packet's data channel. The flags include 4 bits that are used to control other features. The second packet segment 422 is made up of a 4-bit packet type indicator and a 4-bit continuity counter. The packet type identifies the packet as one of the four data types (video, audio, data, or null). When combined with the SCID, the packet type determines how the data packet will be used. The continuity counter increments once for each packet type and SCID. The next packet segment 424 comprises 127 bytes of payload data, which in the cases of packets 402 or 406 is a portion of the video program provided by the video program source 200. The final packet segment 426 is data required to perform forward error correction.

Integrated Receiver/Decoder

[0049] FIG. 5 is a block diagram of an integrated receiver/decoder (IRD) 126 (also hereinafter alternatively referred to as receiver 126 or a set top box). The receiver 126 5 comprises a tuner/demodulator 504 communicatively coupled to an ODU 112 having one or more LNBs 502. The LNB 502 converts the 12.2 to 12.7 GHz downlink 118 signal from the satellites 108 to, e.g., a 950-1450 MHz signal required by the IRD's 126 tuner/demodulator 504. The LNB 502 may provide either a dual or a single output. The single-output LNB 502 has only one RF connector, while the dual output LNB 502 has two RF output connectors and 10 can be used to feed a second tuner 504, a second receiver 126, or some other form of distribution system.

[0050] The tuner/demodulator 504 isolates a single, digitally modulated 24 MHz transponder, and converts the modulated data to a digital data stream. The digital data stream is then supplied to a forward error correction (FEC) decoder 506. This allows the IRD 126 to 15 reassemble the data transmitted by the uplink center 104 (which applied the forward error correction to the desired signal before transmission to the subscriber receiving station 110) verifying that the correct data signal was received, and correcting errors, if any. The error-corrected data may be fed from the FEC decoder module 506 to the transport module 508 via an 8-bit parallel interface.

[0051] The transport module 508 performs many of the data processing functions performed by the IRD 126. The transport module 508 processes data received from the FEC decoder module 506 and provides the processed data to the video MPEG decoder 514 and the audio MPEG decoder 517. In one embodiment of the present invention, the transport module, video MPEG decoder and audio MPEG decoder are all implemented on integrated circuits. This 20 design promotes both space and power efficiency, and increases the security of the functions performed within the transport module 508. The transport module 508 also provides a passage for communications between the microcontroller 510 and the video and audio MPEG decoders 514, 517. As set forth more fully hereinafter, the transport module also works with the 25

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conditional access module (CAM) 512 to determine whether the subscriber receiving station 110 is permitted to access certain program material. Data from the transport module can also be supplied to external communication module 526.

5 [0052] The CAM 512 functions in association with other elements to decode an encrypted signal from the transport module 508. The CAM 512 may also be used for tracking and billing these services. In one embodiment of the present invention, the CAM 512 is a smart card, having contacts cooperatively interacting with contacts in the IRD 126 to pass information. In order to implement the processing performed in the CAM 512, the IRD 126, and specifically the transport module 508 provides a clock signal to the CAM 512. Details of the CAM 512  
10 architecture are described below.

15 [0053] Video data is processed by the MPEG video decoder 514. Using the video random access memory (RAM) 536, the MPEG video decoder 514 decodes the compressed video data and sends it to an encoder or video processor 516, which converts the digital video information received from the video MPEG module 514 into an output signal usable by a display or other output device. By way of example, processor 516 may comprise a National TV Standards Committee (NTSC) or Advanced Television Systems Committee (ATSC) encoder. In one embodiment of the invention both S-Video and ordinary video (NTSC or ATSC) signals are provided. Other outputs may also be utilized, and are advantageous if high definition  
20 programming is processed.

25 [0054] Audio data is likewise decoded by the MPEG audio decoder 517. The decoded audio data may then be sent to a digital to analog (D/A) converter 518. In one embodiment of the present invention, the D/A converter 518 is a dual D/A converter, one for the right and left channels. If desired, additional channels can be added for use in surround sound processing or secondary audio programs (SAPs). In one embodiment of the invention, the dual D/A converter 518 itself separates the left and right channel information, as well as any additional channel information. Other audio formats may similarly be supported. For example, other audio formats such as multi-channel DOLBY DIGITAL AC-3 may be supported.

[0055] A description of the processes performed in the encoding and decoding of video streams, particularly with respect to MPEG and JPEG encoding/decoding, can be found in Chapter 8 of "Digital Television Fundamentals," by Michael Robin and Michel Poulin, McGraw-Hill, 1998, which is hereby incorporated by reference herein.

5 [0056] The microcontroller 510 receives and processes command signals from the remote control 524, an IRD 126 keyboard interface, and/or another input device. The microcontroller receives commands for performing its operations from a processor programming memory, which permanently stores such instructions for performing such commands. The processor programming memory may comprise a read only memory (ROM) 538, an electrically erasable  
10 programmable read only memory (EEPROM) 522 or, similar memory device. The microcontroller 510 also controls the other digital devices of the IRD 126 via address and data lines (denoted "A" and "D" respectively, in FIG. 5).

[0057] The modem 540 connects to the customer's phone line via the PSTN port 120. It calls, e.g. the program provider, and transmits the customer's purchase information for billing  
15 purposes, and/or other information. The modem 540 is controlled by the microprocessor 510. The modem 540 can output data to other I/O port types including standard parallel and serial computer I/O ports.

[0058] The present invention also comprises a local storage unit such as the video storage device 532 for storing video and/or audio data obtained from the transport module 508. Video  
20 storage device 532 can be a hard disk drive, a read/writeable compact disc of DVD, a solid state RAM, or any other storage medium. In one embodiment of the present invention, the video storage device 532 is a hard disk drive with specialized parallel read/write capability so that data may be read from the video storage device 532 and written to the device 532 at the same time. To accomplish this feat, additional buffer memory accessible by the video storage  
25 532 or its controller may be used. Optionally, a video storage processor 530 can be used to manage the storage and retrieval of the video data from the video storage device 532. The video storage processor 530 may also comprise memory for buffering data passing into and out of the video storage device 532. Alternatively or in combination with the foregoing, a plurality

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of video storage devices 532 can be used. Also alternatively or in combination with the foregoing, the microcontroller 510 can also perform the operations required to store and/or retrieve video and other data in the video storage device 532.

[0059] The video processing module 516 input can be directly supplied as a video output to a viewing device such as a video or computer monitor. In addition, the video and/or audio outputs can be supplied to an RF modulator 534 to produce an RF output and/or 8 vestigial side band (VSB) suitable as an input signal to a conventional television tuner. This allows the receiver 126 to operate with televisions without a video output.

[0060] Each of the satellites 108 comprises a transponder, which accepts program information from the uplink center 104, and relays this information to the subscriber receiving station 110. Known multiplexing techniques are used so that multiple channels can be provided to the user. These multiplexing techniques include, by way of example, various statistical or other time domain multiplexing techniques and polarization multiplexing. In one embodiment of the invention, a single transponder operating at a single frequency band carries a plurality of channels identified by respective service channel identification (SCID).

[0061] Preferably, the IRD 126 also receives and stores a program guide in a memory available to the microcontroller 510. Typically, the program guide is received in one or more data packets in the data stream from the satellite 108. The program guide can be accessed and searched by the execution of suitable operation steps implemented by the microcontroller 510 and stored in the processor ROM 538. The program guide may include data to map viewer channel numbers to satellite transponders and service channel identifications (SCIDs), and also provide TV program listing information to the subscriber 122 identifying program events.

[0062] The functionality implemented in the IRD 126 depicted in FIG. 5 can be implemented by one or more hardware modules, one or more software modules defining instructions performed by a processor, or a combination of both.

### Access Card

[0063] A CAM 512 often contains a microprocessor, memory components (a volatile component and a nonvolatile component) and a system input/output module to communicate with transport 508. Traditional microprocessors within a CAM 512 have nonvolatile memory

5 to contain state that is used to provide the desired functionality and enforce security policies intended by the designers. The microprocessor and/or a memory access control unit restricts access to the memory components.

[0064] As described above, attacks may use unforeseen methods or may subvert poorly implemented defenses to gain unauthorized access to the contents of the memory and/or lead to reprogramming the contents of the memory. For example, most attacks occur by inappropriate manipulation of the microprocessor or memory access control unit. Reprogramming or unauthorized access to the memory contents can lead to complete compromise of the security features intended in the CAM 512. The simplest and most prevalent form of attack against the memory component uses external means using the system input/output module due to the low cost of the equipment required to implement this form of attack.

[0065] To avoid this method of attack, security provided by the volatile or nonvolatile memory is not relied upon. Instead, one or more embodiments of the invention utilize a custom logic block that is not subject to manipulation by external, noninvasive attacks. The custom logic block is implemented in solid state hardware that implements a simple and well defined 20 dynamic and/or asynchronous state machine.

[0066] FIG. 6 illustrates the architecture of a CAM 512 in accordance with one or more embodiments of the invention. The CAM 512 contains a microprocessor 602, volatile memory components 604 (e.g., random access memory [RAM]), one or more nonvolatile memory components 606 (e.g., electrical erasable programmable read only memory [EEPROM], erasable programmable read only memory [EPROM], or batter packed RAM), a system input/output module 608, and the custom logic block 610 all of which are communicatively coupled to a system bus 612. As used herein the terms custom logic and hardware state machine refer to the custom logic block 610 in general and specific components of the custom

logic block 610. Thus, a single component of custom logic block 610 may individually and/or in combination with other components define custom logic.

[0067] Allowable functions (for utilizing the digital services) are defined by the state machine hardwired into the custom logic block 610. Additionally, the hardware state machine may be

5 reconfigured. The reconfiguration can occur asynchronously and dynamically across a smart card (CAM 512) population. Implementation in hardware isolates the configuration mechanism from the system I/O module 608, system bus 612, microprocessor 602, or external environment. Accordingly, the state machine is isolated from other components 602-608 and 612 in CAM 512. By preventing the system I/O module 608, system bus 612, microprocessor 10 602, or memory access control unit from direct access to the hardware state machine (within custom logic block 610), previously successful attacks are no longer possible. Thus, any modification or attempt to obtain unauthorized access must be done through extremely 15 expensive invasive attacks to modify the imbedded hardware.

[0068] Ensuring that the decryption and configuration mechanisms are protected from

15 modification preserves the integrity of the CAM 512 that is important to upholding the security model. Thus, the security for CAM 512 is implemented in hardware that is fixed, however, can be reconfigured through a dynamic permutation in the event a specific configuration is compromised. Accordingly, the hardware solution provides a new mode of operation without physically replacing the CAM 512, that can be extremely expensive if the deployed customer 20 base is large.

[0069] FIG. 7 illustrates the architecture for custom logic block 610 in accordance with one or more embodiments of the invention. As illustrated, a dedicated hardware configuration control and IO module 714 that connects to the system bus 612 controls access to components 716-720 of custom logic block 612. Accordingly, the only access to components 716-720 is 25 through the hardware configuration control and IO module 714.

[0070] The hardware state machine 718 may contain the same logic as used in the prior art and may not be modified. In addition to the state machine 718, the implementation consists of a permutation that employs a series of configurable multiplexors at the beginning 716 and end 720

of the fixed hardware state machine 718. Custom logic (i.e., the logic within hardware configuration control and IO module 714) interconnects the multiplexors (within permutations 716 and 720) to the system bus 612 of CAM 512. Accordingly, the hardware configuration control and IO module 714 that connects to the system bus 612 controls access to the

5 permutation 716 and 720 and state machine 718 logic.

[0071] The custom logic within the control and IO module 714 implements a key exchange protocol by accepting (or rejecting) a series of pre-authorized keys (e.g., sequentially wrapped keys with  $n=10^6$  times or other large value) or other secure protocol. The key defines a configuration for the permutations 716 and 720. Valid keys are only known to the headend

10 (e.g., uplink center 104) by using any public key algorithm such as Rabin or RSA (Rivest-Shamir-Adelman). Based on a public key algorithm, the keys cannot be recreated or generated by unknown parties. The keys are delivered to the smart card either over the broadcast stream, Internet, or other appropriate distribution channel. The keys can be delivered to the smart card (i.e., CAM 512) population asynchronously (e.g., over a period of several hours, days, or  
15 months). The keys may be delivered using uniquely encrypted, group encrypted packets. These packets are unintelligible to members (i.e., CAMs 512) for which they were not encrypted. In other words, the packets are only intelligible to those members/control and IO modules 714 having the appropriate private key.

[0072] The hardware configuration control and IO module 714 verifies/authenticates the key.

20 Such a verification/authentication may ensure that the key is from a known source (e.g., a known uplink center 104, program source 200A-200C,etc.), that the key is not a duplicate of an already received key, or that the key fails to comply with an additional security measure. As part of the authentication process, the control and IO module 714 decrypts the keys. The decrypted key is then verified/authenticated by the custom logic within module 714. If the key is  
25 valid, the key is retained by the control and IO module 714 (e.g., by storing the keys in protected registers with no physical or logical output mechanism outside the custom logic within the module 714). If the key is invalid, the key is rejected and may not be stored by the control and IO module 714.

1           [0073] As described above, the key defines a configuration for the permutations 716 and 720. Accordingly, when appropriate, the key is used to dynamically (i.e., on-the-fly) reconfigure the permutations 716 and 720. The timing of the reconfiguration may occur immediately upon receipt of the key. Alternatively, the key may be stored by control and IO

5           module 714 and only used to reconfigure the permutations 716 and 720 (e.g., switch the configuration to that represented by the stored key) upon receipt of an over the air command. In such a circumstance, the control and IO module 714 may store a currently active key (that defines a permutation 716 and 720 currently being used) and a future key. Accordingly, the keys may be delivered asynchronously over a very long period of time to multiple CAMs 512

10          where they are validated and stored asynchronously. Thereafter (e.g., once a period of time has passed to ensure that appropriate/enough CAMs 512 have the new key), an over the air command to activate a reconfiguration operation for a key may be delivered synchronously to all CAMs 512. Thus, the actual reconfiguration operation may occur simultaneously within all CAMs 512, while the key delivery and validation mechanism is asynchronous over a period of time.

15          [0074] To reconfigure the permutations, 716 and 720, the control and IO module 714 communicates bi-directly 722 with the pre-permutations 716 and post-permutations 720 to dynamically configure the series of multiplexors in each respective permutation 716 and 720. Once configured, the pre-permutations 716 place the digital services information received

20          across communication link 724 from control and IO module 714 into the appropriate form for use by the hardware state machine 718. Hardware state machine 718 may modify the digital services information based on custom logic within the state machine 718. Thereafter, the post-permutations 720 may modify the outgoing digital services information to limit use and viewing of the information from unauthorized attackers.

25          [0075] The outgoing information is then transmitted across communication link 724 to control and IO module 714 for use by the system bus 612, microprocessor 602 or other components. It should be noted that while both pre-permutations 716 and post-permutations 720 may be utilized, the custom logic block 610 may only utilize a pre-permutation 716 or a post-

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permutation 720. Nonetheless, regardless of the implementation no direct external access to the permutations 716 and 720 or state machine hardware 718 are permitted.

[0076] FIG. 8 is a flowchart illustrating the use of the custom logic block to provide access to digital services in accordance with one or more embodiments of the invention. At step 800, a

5 security component (e.g., a smart card) receives configuration information (e.g., a configuration key) that has been transmitted asynchronously. As described above, such configuration information may be received through a broadcast stream, Internet, callback, or other distribution channel. Additionally, the configuration information may be encrypted (e.g., through a key exchange protocol such as a public key algorithm). Further, the configuration information may  
10 be received in uniquely encrypted, group encrypted packets.

[0077] When the configuration is encrypted, step 800 may also include the decryption, verification/authentication, and storage of the configuration information (e.g., in one or more protected registers) if the information is authentic.

[0078] At step 802, a hardware state machine (e.g., one or more components of the  
15 hardware state machine or one or more configurable aspects of the hardware state machine) is dynamically reconfigured (e.g., upon receipt of a synchronous command) based on the configuration information. As used herein and referring to FIG. 7, the hardware state machine includes the permutations 716 and 720. Accordingly, the hardware state machine 716-720 is not directly accessible to a system input/output module 608 or system bus 612 of CAM 512.  
20 Instead, the hardware configuration control and IO module 714 connects the hardware state machine 716-720 to the system bus 612 and controls access to logic of the hardware state machine 716-720. The dynamic reconfiguration may comprise dynamically reconfiguring a permutation that employs a series of one or more configurable multiplexors at the beginning and/or end of the hardware state machine 718.  
25 [0079] At step 804, the custom logic block 610 controls access to the digital services through the configurable hardware state machine 716-720. In other words, digital services are received, processed through the pre-permutations 716, processed by hardware state machine 718,

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processed through post permutations 720, and made available on the system bus 612 for further use.

Conclusion

5 [0080] The simplest and most prevalent form of attack against a memory component of a smart card uses external means using the system input/output module due to the low cost of the equipment required to implement this form of attack. To avoid this method of attack, access to a dynamically reconfigurable decryption engine is via custom hardware and not directly connected to the system I/O module, system bus, or microprocessor. The custom logic block is

10 10 implemented in hardware that implements a simple and well defined state machine that is not modifiable by noninvasive means.

[0081] As described above, custom hardware has been extensively used in smart cards/CAMs 512 throughout the electronics industry. However, the smart card based custom hardware implementations have not attempted asynchronous and/or dynamic reconfiguration of

15 15 the hardware state machine so that the state machine takes on a significantly different hardware based encryption/decryption engine. Embodiments of this invention attempt to secure the smart card by implementing a dynamic and asynchronous hardware state machine that is isolated from the external environment and not modifiable through noninvasive, external attacks. Further, while the decryption and configuration mechanisms of the invention may still potentially be

20 20 modified through sophisticated, costly and time consuming invasive attacks in which the actual hardware is modified, many advantages exist to utilizing the present invention.

[0082] For example, protecting a hardware state machine through dynamically reconfigurable custom hardware is important because it prevents low cost attacks. Low cost attacks are prevented since hardware state can only be reconfigured by a custom logic block and cannot be

25 25 reprogrammed by the microprocessor. Preventing low cost attacks forces attackers to use expensive invasive attacks that are not available to the vast majority of pirates. Inhibiting his simple form of attack prevents intruders from using attacks that require only a computer and an inexpensive (e.g., \$10) card reader. Additionally, further compromise of one device through an

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internal, invasive attack does not lead to a successful attack through a low cost, external attack. Thus, by preventing the system I/O module 608, system bus 612, microprocessor 602, or memory access control unit from direct access to the digital services custom logic (e.g., a decryption engine and/or configuration mechanisms) contained in a hardware state machine

5 716-720, previously successful attacks are no longer possible.

[0083] Further, the custom hardware implementation can withstand substantial external attacks without inappropriately modifying the security provided by the smart card. Also, reconfiguration extends the life of the custom hardware implementation and that of the security provided the smart card. Extending the life of the smart card postpones card replacement,

10 thereby, keeping operational costs low.

[0084] This concludes the description of one or more embodiments of the present invention. The foregoing description of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching.

15 Accordingly, while the invention may protect video, audio, broadband and data services reception using a microcircuit that resides in a smart card and set top box, the invention is not limited to smart card applications or to a particular digital service system.

[0085] It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto. The above specification, examples and data provide 20 a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.